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THE RICE WORM (*TYLENCHUS ANGUSTUS*) AND ITS CONTROL

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The area affected and the extent of the damage.

In a previous publication[1] an account was given of a new and exceedingly serious disease of rice, called locally " ufra," in the great rice-growing deltaic tract at the head of the Bay of Bengal.

This tract comprises one of the main rice areas of India. The districts actually known to be affected (Noakhali, Tippera, Dacca, Faridpur, and Backergunge) contained, in 1916, nearly 6 million acres out of the 21 million acres under this cereal in Bengal. Adjoining them are other districts so similar in climatic conditions and agricultural practices that they are liable to infection and indeed are likely to be, in some cases, already infected. This threatened area adds another 6 million acres of rice in Bengal and over 2 million acres in Sylhet. In all of this vast extent rice occupies over 70 per cent. of the cultivated land; hardly any alternative food crop is grown, and the great bulk of the tract is totally unsuited to any other. Hence it is probable that no plant disease hitherto observed in India, except the cereal rusts that periodically take heavy toll of the wheat crop in Northern and Central India, possesses such potentialities for harm as ufra. The intensity of the attack no less than the importance of the crop affected warrants this view.

In most of the districts referred to, communications are defective and agricultural intelligence is backward. While the paddy is growing, the fields

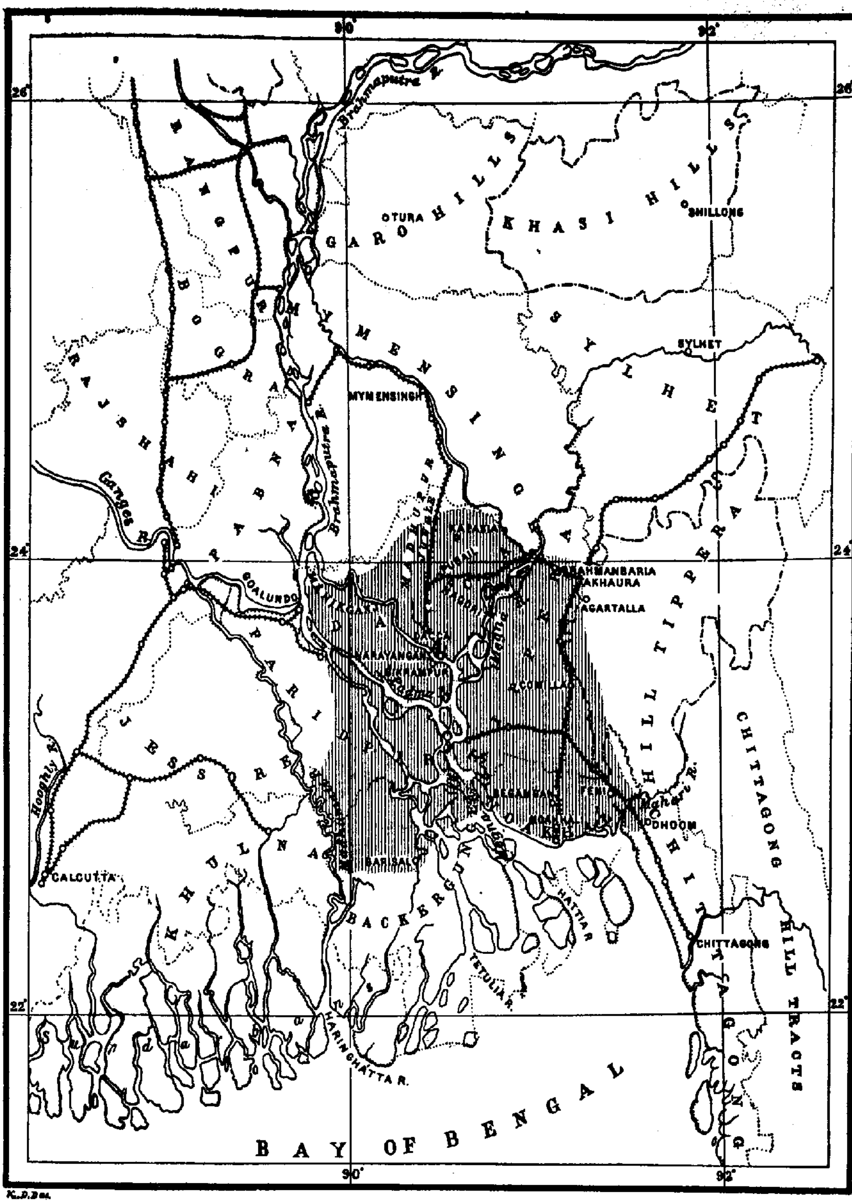
[1] Butler, E. J. "Diseases of Rice." *Agric. Res. Inst., Pusa, Bul.* 34, 1913.

are submerged with flood water from a few inches to 12 feet or more * in depth. Traffic is confined to boats, except along a few high-roads. The water falls after the rains, and at the time when the disease is at its height even boat traffic becomes difficult outside the main waterways. Ufra may remain undetected unless the fields are actually visited, and this is not always as easy as it appears. Where, as is often the case, the disease is not recognized as such but attributed to thunder or other uncontrollable agencies, outside assistance is not invoked. The cultivator considers himself unfortunate, but it does not occur to him to report his misfortune to the authorities. The agricultural staff, ridiculously small for the area, may be long before it learns that anything is wrong. Thus there are large tracts in Faridpur and Backergunge where much damage has been done for the past 10 years but which were only discovered in 1916. When boat traffic is easy, ufra is in its earliest stage in the winter crop and hard to detect; when, on the other hand, the ground is dry enough for walking, the harvest is over. In certain places it has been noticeable that the reports of damage observed by the staff employed in surveying the infected districts are chiefly from the vicinity of waterways that are practicable in November, the season when the disease is most easily recognized: the hitherto recorded outbreaks in Faridpur and Backergunge are confined to the neighbourhood of large "chars," or swamps that hold water well into the cold weather. It is highly probable that such cases do not entirely represent the truth, that the large areas which are difficult to reach as the paddy ripens, owing to the fall of the water, are equally ravaged by the disease. In further support of this view is the fact that in the Dacca District the villages from which ufra has been reported are mostly accessible in the rains from the high land that extends north of Dacca town towards the Madhupur Jungle; or from the navigable waterways. No report was obtained from the Manikganj Subdivision, less easy of access, until a special search was made in 1917, when it was found heavily infected.

Hence it is quite impossible as yet to form an accurate estimate of the extent of the infected tract or of the amount of damage caused by the disease. The accompanying map gives roughly the limits of the disease as at present known.

The southern limits of the infected area were accurately defined east of the Meghna, in August, 1917. They are, from east to west, the villages near Dhoom just south of the Mahari and Bara Feni rivers (which have been crossed

* I have seen a fair crop of paddy in a field where the measured depth of water exceeded 12 feet.



Map showing area known to be infected by the rice worm in 1917 (shaded area.)

District boundaries.........

Railways

Scale: 1 inch = 48 miles.

since 1913), and from thence to the estuary of the Meghna by a line passing to the north of Noakhali town. West of the Meghna, in the district of Backergunge, the disease was found in 1916 from Barisal to the borders of Khulna District at the river Madhumati, but the exact limits of the extension south and east of this area are not known. In the eastern section of this boundary further spread southward is checked by the sea and by the Chittagong Hills and a narrow belt between the hills and the sea where the land is relatively dry and no swamp paddy is grown. No trace of ufra has been found in the swamp paddy areas near Chittagong town. West of the Meghna, the limits so far observed are not coincident with any topographical feature of importance, and there seems to be no reason, beyond the comparatively recent origin of the disease and the slowness of its spread, why it should not extend into Khulna and the Sundarbans, at the head of the Bay of Bengal.

To the east, the infected area is limited by the highlands of Hill Tippera; but between these and the district of Mymensingh is an area in which extension is going on towards and perhaps into Sylhet. It is known to have reached Akhaura, about 10 miles from the Sylhet border, in 1913. There appears to be no obstacle sufficient to save the very large rice area of Sylhet from infection.

The same applies to the almost equally important rice tract to the north in Mymensingh. Ufra has been traced through Dacca to the Mymensingh border east of the Madhupur Jungle, and probably extends further north. In this direction it is unlikely to be checked by any natural obstacle until the Garo Hills, which bound Mymensingh on the north, are reached.

Westwards, the Brahmaputra is not known to have been crossed north of its confluence with the Ganges. South of this, however, there is a large infected tract on the west of the Padma (as the river is now known), in the district of Faridpur. The western limits of this extension are unknown, but there is some reason to hope that the relatively dry area of Jessore may check westward spread. But extension into Khulna, further south, is, as already mentioned, highly probable, and along this line there appears to be nothing to prevent infection of Central Bengal up at least to the Hooghli.

The immediately threatened areas are, therefore, Sylhet to the east, Mymensingh to the north, and Khulna (with possibly some of the districts across the Brahmaputra) to the west.

As regards the losses sustained only isolated instances can be given. Total loss of the crop in individual fields is not uncommon. I have seen such cases in Noakhali, and the Collector of Dacca saw large areas near Pubail, in 1916,

where the crop was so poor that it was not worth cutting and the cattle were turned loose to graze it. The same officer reported total loss of the winter rice crop in Raban village that year. In Begumganj thana of Noakhali District the loss in 1910 was roughly estimated at 200,000 maunds (about 7,400 tons) of grain. In October, 1913, most of the cultivators in certain parts of Feni were found cutting their winter rice for fodder, as they expected no grain owing to a very severe outbreak of ufra. The average annual loss in the village of Kapasia (north-east of Dacca District) for the four years 1911—14 was estimated by an officer of the Bengal Agricultural Department to be Rs. 55,800, distributed over 1,600 acres of deep-water paddy, or an average annual loss of nearly Rs. 35 per acre. In a limited number of villages further south the same inquirer calculated the loss to exceed 1½ lakhs of rupees annually. In the Portuguese settlement at Nagori, east of the Madhupur Jungle, the average for the four years ending 1914 was said by a Revenue officer to be over Rs. 20,000, distributed over 1,248 acres of cultivated land, of which about two-thirds were annually attacked. This gives a loss of Rs. 16 per acre of the cultivated land or Rs. 25 per acre of that annually attacked. Examples could be multiplied, but enough have been given to show that in certain parts of the infected area the disease has created an economic problem of considerable magnitude since no other food crop can be substituted for the rice now grown. But it is impossible to form any reliable estimate of the total amount of damage caused in the whole tract.

It is equally difficult to form an accurate estimate of the length of time the disease has been known in various parts of the infected districts. Only in Noakhali is there good evidence that it has existed for 20 to 30 years. As the limits of extension are approached, it is quite clear that we are dealing with a new and spreading disease. Many villages have been visited where it has appeared within the last five years, and a few have only recognized it during two or three years. The people between Feni and Comilla say it reached them from the south-west, *i.e.*, from the direction of Noakhali, and on the whole it seems likely that it originated somewhere near the mouth of the Meghna. Whether it reached India from some external source or began by a previously harmless organism developing parasitic tendencies is an interesting speculation. Very many of the so-called "new" diseases of plants have been found subsequently to be endemic in the less explored parts of the world. I have recently[1] collected a number of such cases and brought forward

[1] Butler, E. J. "The dissemination of parasitic fungi and international legislation." *Mem. Dept. of Agric. in India, Bot. Ser.*, IX, No. 1, 1917.

a mass of evidence to show that practically all the new fungal diseases of plants that have appeared in Europe and the United States of recent years are importations. The increasing intercourse with distant parts of the world and the constant shortening of voyages have been the chief factors in disseminating disease. The organism that causes ufra is subject to much the same limitations of extension as fungi ; and it is far from unlikely that it will be discovered in some of the countries with which India is in communication by sea and where the diseases of crops have not yet been investigated.

Incidence of ufra in different types of paddy.

The many hundreds of varieties of paddy grown in Eastern Bengal may be grouped into three main classes. The *boro* or spring paddy is sown in November to January and harvested in April-May. The *aus* or autumn paddy is sown between March and May and harvested between July and September. The *aman* or winter paddy (the main crop) is sown at about the same time as the aus but the harvest is in November-December.

The aman is the chief crop, accounting for over two-thirds of the acreage under rice. The number of its varieties is legion. In any given locality, types will be found suitable for the different levels of land. These levels, though slightly marked, are of the utmost significance in paddy cultivation. The general fall of the land, as in most deltas in the making, is away from the river channels, and the water in the small channels flows away from and not towards the main streams. So also, at least in Noakhali, the land does not slope towards the sea, the coastal belt being generally higher (and therefore growing more transplanted paddy) than the parts lying more to the north. Between the main river channels the surface sinks into basins, but little above sea level. Numerous semi-permanent swamps or " chars " are formed, but the deposition of enormous volumes of silt is constantly changing the outlines of these, and the cultivated margins tend to increase. The deposition of silt is not uniform, and further irregularities are caused by the varying courses of currents during flood time. The hand of man accentuates these differences of level by terracing and embanking ; and a field six inches or a foot higher than those around it will often grow a different variety of paddy. In general, the lowest fields grow the worst kinds, and the cultivator naturally aims at raising his land where he can. Three or more different levels, each with a different paddy, will often be found in one holding.

Nevertheless there are great tracts unsuited for any but the so-called deep-water or long-stemmed kinds. In many places they form the greater

part of the crop. The stalks of these varieties may be up to 20 feet in length and they grow astonishingly fast; it is said as much as 9 inches in 24 hours. The lowest land, where they are found, is subject to early inundation, and the crop is sown broadcast very early in the year, so as to ensure a good start before the flood rises.

At a slightly higher level another large group of forms is found. In Noakhali these are often mixed with aus, each class being harvested as it ripens. In other districts the lower slopes (but not the bottom) of the sloping basins grow these forms, often in several tiers each occupied by a different kind. These are also broadcasted, the date of sowing depending on the level and the consequent normal period of submergence.

It is in these two groups of aman rices that ufra is most prevalent. It is true that other varieties are sometimes attacked, but on the whole it may be said that the disease is found chiefly confined to the lower lands.

The higher levels grow the better quality transplanted group of aman paddy. This group includes the sail or roa rices, which are the best grown in the district. The flood does not reach these levels until comparatively late in the season, and there is time to grow the seedlings in seed-beds and transplant them out before the water is more than a few inches deep. Indeed, in many places it is possible to take a crop of aus or jute first and then transplant the field with aman in August-September. Some of these transplanted amans, however, are suitable for fairly low ground. Thus in Feni and Chittagong several of the *roacha* paddies can be transplanted when the seedlings are as much as two feet in height and can survive if put in 18 inches of water: these kinds may also be broadcasted.

As a rule, the fields intended for transplanted aman are better cultivated than those at a lower level, and even grow winter (*rabi*) crops of pulses, coriander, onions, and garlic at times, after the paddy is harvested.

No authentic case of ufra in any of these transplanted amans has as yet been seen by the writer, though there have been a few reports of damage in transplanted winter rice in Dacca and Noakhali, and the Feni cultivators say *roacha* may be attacked if transplanted in low land that bore a diseased broadcasted crop the previous season. It is also practically certain that transplanted aman which follows a diseased aus crop may get attacked, judging by statements made to the writer in Noakhali.

Aus paddy accounts for between a quarter and a third of the acreage. It is usually broadcasted, but in relatively high land is transplanted. The straw is short and at harvest little stubble is left, especially in transplanted

fields. In the more recent parts of the delta it is common to grow a mixed crop of aus and aman (called *bajal* in Noakhali), both being broadcasted together early in the season, the aus ripening in July or early in August and the aman in November-December. Very early maturing aus is also broadcasted pure on fairly low land in this district, and after harvest in July is followed by transplanted aman, the water being then only a few inches deep. Ufra occurs frequently in both these kinds of aus, in Noakhali and Backergunge, but not in that which occupies higher land or which is transplanted. In Dacca District aus is rarely (if at all) attacked.

The boro paddy is much less important than the others, occupying only about one-fiftieth of the rice area. It is almost unknown in some districts, such as Noakhali, but in others, such as Dacca, there is a good deal. It is found in the lowest land, where water can be held by embankments during the dry season. As this dries out, irrigation is required, the water being lifted from the permanent channels which form a network throughout the district. The boro fields are thus confined to the margins of the latter. It is always transplanted, except on the mud flats of the main channels where it is sometimes broadcasted. It is not attacked by ufra so far as has been ascertained up to date, though there is an unconfirmed report from Gobindapur (Dacca District) that occasional signs of attack have been seen in January.

Thus, in general, the paddy grown on high and relatively high land, including the whole of the transplanted kinds, escapes ufra ; while of those kinds grown on the lower land, only such as are harvested during the moister half of the year, from July to December, suffer. The explanation of this most important phenomenon is connected with the life-habits of the worm and will be reserved for a subsequent section.

Date of appearance of the disease.

Ufra has been observed in aus paddy in Noakhali District in the first half of June. This is the earliest attack hitherto recorded in the field, the crop having been about 2 months old, broadcasted unmixed aus, growing in about a foot of water and therefore on quite low land. In July and August, as the aus ripens in the southern part of the infected area, the attacks are more frequent. The aman is most severely injured from October to harvest time, but cultivators have pointed out to the writer what they detected as early stages of the disease at the end of July and subsequent dissection has confirmed the diagnosis though the external symptoms were obscure. The second growth which appears in very wet aman fields from December to February

is also attacked, and these attacks have been found as late as the middle of February in Noakhali. Between February and June no case of ufra has been seen under natural conditions, though, as will be described below, it is possible to secure successful inoculations in the laboratory during this period.

It is not easy to detect the early attacks, as the symptoms are not well marked on seedlings or even up to the time the young ear begins to form within the bud. There is little change except a somewhat stunted growth and a pallid appearance of the upper leaves. The most recently expanded leaves are either chlorosed as a whole or are marked by pale longitudinal streaks. They are also somewhat thinner and more flaccid than the normal. But it is only later, when brown marks appear on the leaf sheaths and the ears become altered as described in the previous paper, that recognition is easy.

The length of time after infection has occurred before symptoms can be detected varies greatly according to the age of the plant and to other conditions connected partly with the season of the year. On very young seedlings symptoms of chlorosis have been detected within a week of inoculation. On larger plants it may take from ten days to six weeks before the symptoms are definite. When natural infection results from the stubble left from the previous crop it may take two to four months before the disease becomes evident, and this is the most usual experience in field outbreaks in the infected area. It will be seen below that it is possible to offer an explanation of these variations.

The cause of ufra.

The cause of ufra was ascertained in 1912 to be a hitherto undescribed nematode worm (" eelworm "), which was named *Tylenchus angustus* and described at length in the previous paper. When recorded no other parasitic *Tylenchus* was known which resembled it in its life-history or biology. Recently, however, a serious black-currant disease has been found near Cambridge, England, caused by another previously unknown species, *Tylenchus ribes* Taylor,[1] which has many points of similarity in habits to the rice worm, though morphologically quite distinct. It is evident, therefore, that there are more than one species of this well-known genus of nematodes which are characterized by an ectoparasitic life on the above-ground parts of plants, the individuals remaining on the surface of the parts attacked (without actually entering the tissues as most of the parasites of this group do) and

[1] Taylor, Miss A. M. " Black currant eelworm." *Journ. Agric. Science*, VIII, 1917, p. 246.

feeding by sucking out the juices through a minute hole bored by a tiny spear which can be protruded from the mouth. That other such forms exist besides the two already described is very probable, since they are as readily overlooked by entomologists as by mycologists. They are neither insects nor fungi, nor do they cause any such characteristic symptoms as would lead to their presence being specifically looked for. In spite of their simple mode of parasitism they can, as the rice worm shows, rank with the most harmful enemies of plants yet described.

Tylenchus angustus feeds, so far as can be ascertained, exclusively on living rice. Attempts to grow it in artificial media have failed, and a search through the infected area has equally failed to reveal it on any other plant than rice. It can remain alive, in the absence of food, for considerable periods, but its growth is very limited and no moults occur except those which were due when removed from the living plant. After emergence from the egg there is some increase in size in water, but this never progresses to the first moult The later larval stages increase little, if at all, in water. It is not certain whether the final (sexually perfect) stage can reach full maturity in water if liberated while still immature, but the perfect female may lay eggs for a short time in water. Copulation does not occur in water, as many thousands of adult worms have been kept under observation in this medium without any trace of the sexual act having been seen. In dry air the worm can remain alive for considerable periods, but it remains entirely passive, neither moving, nor feeding, nor growing, nor copulating. There is, therefore, no multiplication of the worm in these conditions, except that a few eggs may be laid in water and a few of these may possibly hatch out into the first larval stage, though as a rule only such eggs as are mature when removed from the plant seem to hatch when totally immersed. Though the worm may remain alive and wander considerably on various solid media for several weeks, no increase in numbers has been obtained in this way, but further considerable trials will be necessary before it can be concluded that artificial culture is not possible.

The worms may be induced to attack paddy at any time of the year if properly handled. Nevertheless there are great differences in behaviour at different seasons, and to understand these it is necessary first to describe the life-history of the parasite when unable to obtain suitable living food.

The non-parasitic life of *Tylenchus angustus*.

Normally the active life of the worm, as indicated by the appearance of symptoms of injury to the plant, extends from June to November in the

southern part of the infected tract, rather later in the northern. At any period during these months it is possible usually to find plants with numerous worms actively feeding. Such worms when removed to water are intensely active, swimming about with great vigour. In swampy ground, where a second growth takes place from the stubble after harvest, this period may be, as already stated, extended to February. But in the vast majority of cases, the parasitic life ceases before harvest in late November or early December.

At this period, as the host plant dries up in ripening, the worms cease feeding, coil up, and pass into a resting condition. The position on the plant which they occupy after the ears emerge is the base of the peduncle, the stem just above the next node lower down, and within the glumes in the ear. Here they may occur in clumps or masses, visible to the naked eye as cottony tufts or a grey coating on the surface of the affected parts, but they are often isolated more or less completely and sometimes very scattered. The species is, therefore, less gregarious in its habits than appears to be the case with *Tylenchus ribes*. Each worm usually forms a separate coil and the coil is usually quite circular (Fig. 1). The tendency to coil is a result of desiccation as a rule, since at any time of year coiling may be induced by drying out the medium gradually. Occasionally coiling has been observed to result from the action of weak poisons, but the ordinary fixatives that are not of rapid action usually kill the worm in an extended position, though there may be a short preliminary tendency to coil.

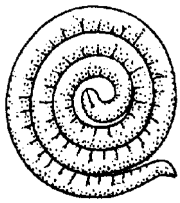


Fig. 1. *Tylenchus angustus*: coiled individual.

After coiling is completed, immersion in water leads to uncoiling. This may happen even after the worm is dead; at least it has often been observed that old coils straighten out in water but undergo no further movement and gradually decompose. The coiled worms are apparently protected in some way (possibly by a mucous coating) from ready decay, and it has often been extraordinarily difficult to decide whether a worm is alive or dead after placing in water. Usually it is safest to rely on the resumption of active motility * for determining that life persists. If the period of desiccation has not been long, motility sets in soon after immersion, but after two months or more in the dry condition it may take over an hour to commence, though uncoiling is usually complete within the hour. To give a specific instance where doubt remained as to the worm being alive, a double coiled worm that had been dry

* By active motility is meant progression, or at least definite wriggling.

for 15 weeks uncoiled slowly to about half of full extension when placed in water. The body was highly vacuolate—indeed almost empty—and no other motion was observed in 18 hours. Yet on adding weak picric acid slight recoiling, to about half the original coil, occurred. Other worms from the same batch decomposed in a few days after uncoiling in water, so that if not dead they were at least moribund. Worms liberated in such a condition in a flooded paddy field would be quite unable to reach the paddy plants or to climb up any that they accidentally come in contact with, so that for practical purposes, in considering the period during which desiccated worms are capable of reinfecting the crop, the resumption of active motility may be taken as a measure. This period exceeds the time required to fill in the gap between the harvest of the aman paddy and the first records of the disease in the aus. Thus worms dried out on their host plants by digging up the latter and removing to the laboratory in the second half of November, 1916, resumed active motility on being placed in water early in June, 1917. The power of uncoiling in water persists much longer, for at least 15 months, but I have not observed active motility after so long an interval, nor would the worm be ever likely to require such a period of rest in the paddy plains of Eastern Bengal before finding conditions of moisture and fresh food which would enable it to resume its active parasitic life.

Life is not so prolonged when the worm is totally immersed in water. Many die in a few days but some may survive for more than a month. The following experiments in 1913-14 illustrate the variations observed. On September 8th, 1913, a number of active worms in all stages were sown in drops of rain water on 4 slides and kept in a moist chamber. The majority were motionless and apparently dead 5 days later. In 11 days all were dead on 2 slides, but a few were still motile on the other 2 slides. The dead ones decomposed gradually and all had decomposed by December 1st when the slides were again examined. On October 9th, 1913, several more slides were similarly prepared but tap water was used. All were dead and decomposing by December 1st (*i.e.* in 52 days). On December 1st, 1913, another batch of 3 slides was prepared in the same way as the last. Many of the worms in all stages were alive and motile after 24 days and about 50 (mostly adults and medium-sized larvæ) after 5 weeks. On January 6th, 1914, from 20 to 30 active worms (mostly larvæ) were sown in a glass capsule in distilled water with some germinated paddy seedlings. The seedlings were removed after 4 days, with one or two worms that had climbed up them. Of those left in the capsule (over 20) only one living could be found on January 26th.

When kept under intermediate conditions between total immersion and dryness, life may be maintained for several months. Kept on slides under bell jars in a saturated atmosphere some have been found still alive after 4 months. Under such conditions they have a certain degree of motility, as will be explained later, and they live decidedly longer than when totally immersed, though less than when desiccated.

Both longevity and motility, away from the host plant, are influenced by other conditions than moisture. Temperature and light are amongst these. In one experiment a number of worms that had been dried on the host plant for two months were sown in tap water on several slides. All the worms were from the same piece of infected peduncle. They were sown on January 29th, 1917, and resumed active motility after about half an hour. Two of the slides were placed in an incubator at 31°C., in a saturated atmosphere, in the dark. Another was kept in a saturated atmosphere on the bench near a window; and a fourth close by under similar conditions except that it was covered with a dark shade. The bench temperature varied from 16° to 19°C. during the next week and then gradually rose, reaching a range of 21° to 23°C. after a month. On January 30th the worms in the incubator were moving actively, as were those exposed to light on the bench, while those in darkness on the bench were very sluggish. The following day these differences were accentuated. The darkened worms in the incubator were exceedingly active, while those in darkness on the bench had ceased swimming and were merely coiling and uncoiling or bending from side to side slowly. Those exposed to light on the bench were swimming a little less actively than those in the incubator. Here both light and warmth had stimulated activity, the latter somewhat more than the former. On the 23rd of February all the worms in the darkened chamber on the bench were dead, while those exposed to light were still alive in fair numbers though now only moving sluggishly and mixed with a good many dead. In the incubator, on the other hand, most of the worms were still living and very active in the water. The drops were replenished on this day. A month later some were still alive and moving in the drops in the incubator. By the 13th May there was only one worm left alive in the lighted chamber at laboratory temperature (now ranging from 27° to 29°C.) and that one had migrated from the drop, while there were still many in the incubator. The water in the latter had dried to a thin film in which no living worms were left, but living worms were scattered over the rest of the slide, singly or in small groups, and feebly motile. On adding water they promptly became actively motile again. As the incubator had now ceased working owing to the rise in temperature, the slides

were kept on the bench exposed to the light, and a few worms remained alive until May 30th. Thus in prolonging life, as in stimulating motion, both warmth and light were favourable, the former more than the latter.

The experiment was repeated during warmer weather, when the laboratory temperature ranged from 30° to 32°C. Worms that had been dried on the host plant for 18 days were much more sluggish at this temperature when kept in darkness than when exposed to light for several days after sowing in water, whereas in another batch, only 7 days after collecting, there was no appreciable difference. This suggests that starvation may also influence activity. All were almost equally sluggish after the worms had lain in water for 16 days. In a cool incubator at 23°C., in the dark, activity was much reduced, but was stimulated even after 4 weeks when warm water was added. Longevity was not tested in this experiment, owing to failure to keep the worms from wandering.

Wandering of *Tylenchus angustus.*

When the study of this worm was first taken up, its remarkable activity in water, combined with its immobility on the plant, led to the hasty conclusion that free liquid was necessary to enable it to wander. The plants were naturally examined in rooms in which the air was relatively dry, and under these circumstances nothing beyond an occasional contraction of the body was noticed when the worms were watched through the microscope on the stem and leaves of rice. It has now been fully established by repeated observation that free liquid is not necessary for travelling, but that the worms can move slowly, but none the less through considerable distances, in a saturated or very damp atmosphere. As this is one of the most important factors in explaining the periodic incidence of the disease, it requires to be further considered.

The first indication of migration in a saturated atmosphere was obtained while drops of water, containing a known number of worms, were kept under observation for long periods on slides in a moist chamber. After one or more days some of the worms were missing. When this had occurred several times, accident revealed the missing worms on other parts of the slide, often near the edge, which they apparently find difficult to pass. If examined immediately on removal from the moist chamber, or in slides prepared as for the well-known "hanging drop" method of examination, they can be seen to move slowly by a snake-like method of progression. On open slides progression soon ceases when exposed to room dryness, but it starts again if the slide be

breathed upon. In moderately dry air, or even under such conditions of humidity as ordinarily occur in the laboratories at Pusa during the monsoon months, movement on a dry surface is apparently impossible. In air that is approximately saturated, moisture is condensed round the body of the worm, appearing as a film or sometimes a minute droplet, in which movement is relatively free. In such conditions worms have been found to pass round to the under surface of the slide, and even to travel on to other slides on benches above or below that on which they were placed in the moist chamber. Not only can they move on dry surfaces in a saturated atmosphere, but they can enter and leave drops of water, though the latter cannot be easy if the resistance caused by surface tension be taken into account. Some batches examined seem to have had a much greater tendency to leave the drop of water in which they were sown than others, and it is tempting to suppose that this is due to a copulatory instinct. At any rate, it has been observed that the worms that have left a drop often come together in twos or threes, and in several cases a male and a female have been found applied together, either extended or partially coiled over one another, though actual copulation has not been seen. Under no other circumstances has the writer observed anything of the kind, and he is fairly satisfied that copulation must take place in a saturated atmosphere, without free liquid, though perhaps confined to worms on the living host plant. It should be mentioned, however, that larval stages have occasionally been seen to possess the same instinct as the perfect forms.

Several of the earlier inoculations carried out at Pusa failed owing to ignorance of the above facts. They were made on plants growing in pots in the laboratory with no precautions to keep the air around the plants near the saturation point. In some the worms were inserted within the leaf sheaths; in others worms or eggs or infected pieces of paddy were placed in water around the base of the plants. Field inoculations carried out in the same way succeeded in every case when performed during the monsoon months. During this period the humidity is always high, and the air surrounding the plants, especially when, as was the case, these grow close together, is probably approaching saturation. It has now been found that to get successful results in laboratory inoculations the air must be kept moist by the use of bell jars or other similar means. Only under very exceptional conditions of humidity have attempts at inoculation within-doors on uncovered plants given any result (*see* Expt. III on p. 20).

We can now understand several of the peculiarities in the incidence of the disease under natural conditions. As already stated, the boro paddy, which is grown during the period from January to April, escapes the disease. This

it does even though the boro fields may adjoin badly diseased fields of aman paddy. There cannot be the slightest doubt, from what I have seen, that boro fields are often contaminated with infected stubble from the aman crop. The boro is transplanted into these fields usually within a month of the aman harvest, and the fields themselves usually occupy the lowest land, bounding the banks of the permanent *khals* or waterways that run through the centre of the rice *bils* along the natural drainage lines of the country. Around them are great stretches of land suitable for the deep-water aman in which ufra is most prevalent. As the boro fields are kept permanently flooded, and as some of the infected aman stubble must certainly find its way into them, their water must contain free-swimming worms. Experiments carried out at Pusa have proved that the parasite is only too ready to attack paddy at this period, provided the moisture conditions are kept suitable. Hence there must be some explanation connected with the conditions of the environment to account for the general escape of the boro cultivation. This explanation is to be found in the dryness of the air between February and May as compared with that of the rest of the year.

The following table, abstracted from data collected by the Meteorological Department (*Ind. Meteoro. Memoirs*, XXII, p. 460), gives the monthly normals of relative humidity at a series of stations in or at the borders of the infected area :—

Monthly normals of relative humidity.

Locality	Number of years	January	February	March	April	May	June	July	August	September	October	November	December
Chittagong	22	88	83	82	80	81	86	88	88	88	89	88	89
Noakhali	22	89	85	84	81	83	88	90	90	89	88	87	88
Barisal	22	87	84	84	82	82	87	89	89	88	84	84	86
Brahmanbaria	6	87	82	79	80	82	87	88	87	86	85	80	84
Narayangunj	22	88	83	83	83	84	89	90	90	88	85	85	87
Goalundo	6	86	81	76	77	79	85	87	86	84	80	79	83

In all stations the maximum rise in humidity (5 or 6 per cent.) takes place between May and June, and in none (except Noakhali in February) does the humidity between February and May reach 85 per cent. Between June and September the humidity remains above 85, except in Goalundo, where it falls to 84 in September. It may be added that heavy night dews persist after the rains until well into February, but thereafter diminish and disappear as the hot weather sets in. Since the records are taken at 8 A.M., it is probable that

the vaporisation of the morning dews affects the readings, and that midday or afternoon records would give lower relative readings in the early months of the year.

It has already been pointed out that *Tylenchus angustus* lives and feeds towards the top of the rice plant. To reach this position it must be able to mount the plant, emerging from the water at its base and climbing up the parts above water. This it cannot do, as explained above, unless the surrounding air is at a point approaching saturation with water vapour. The same condition is necessary to allow it to spread from one plant to another. No doubt when the boro paddy is first transplanted, some of the worms should be able to make their way between the folds of the leaf bud at the water level and reach a position suitable for feeding and even for multiplying. It is probable that there is some injury to the crop at this stage (the more so since the second crop of aman shoots has been found infected in January and February), but it would not attract much attention; the symptoms, as already pointed out, are not very definite on seedling plants; and the injury would most likely be attributed to the check received during transplantation. Once the rice shoots had grown well above the water, further multiplication of the worm would cease, and further infection of the susceptible parts would become impossible, as its migration would be prevented by the dryness of the air; those worms that had failed to get out of the water would die after a month or two. Thus the characteristic attacks as the crop ripens would fail to develop.

This explanation of the immunity of the boró crop has been considerably strengthened by observations made in 1918 on the second growth of infected aman. A field on the Dacca Experiment Station was found to have the young shoots and dwarf ears that grew from the stubble of diseased winter rice in January (after harvest in December) heavily infected, while those that grew in February entirely escaped. The infected and clean shoots were often within a few inches of one another, yet the worms were unable to reach the latter, though, when immersed in water, they were found to be highly motile. The February attacks observed in Noakhali are probably correlated with the higher humidity of that district.

The same factor serves to explain the remarkable differences that have been observed in the length of time between infection and the appearance of the disease, according to the season of the year and the method of infection employed. In field inoculations carried out during the monsoon, the first symptoms may be observed in about 8 days where the worms are directly

inserted under the leaf sheaths[1] and in about a month when worms are added to the water in which the plants are growing. When infection comes from the stubble of a previously diseased crop, the period depends on the season or, to be more exact, on the humidity. The following are some of the results obtained at Pusa :—

(1) Seed broadcasted in a plot, which contained stubble from a diseased crop of the previous season, on March 28th, 1913. Ufra distinct by the first week in August, though some doubtful symptoms were seen as early as May 12th.

(2) Seed self-sown from a preceding diseased crop in December, 1915, and germinated during the first three months of 1916, coming up through the rotting stubble. Ufra first clearly seen on July 24th.

(3) Stubble removed from a diseased plot on December 3rd, 1913, and seed broadcasted, returning some of the infected stubble, on the same day. As germination was backward and not sufficient to fill the plot, some plants were transplanted into it in January and February, 1914, and some more seed was broadcasted on March 5th. Ufra was first found in a plant of the first batch sown, on June 17th, and was seen in all three batches on July 10th.

Thus whatever time the seed is sown at Pusa, between the beginning of December and the end of March, ufra definitely develops (when the infection comes from worms left in the stubble from the previous crop) only when the air humidity rises after the rains break in June. When sown early, there is little growth before March or April in Pusa, but the worm is not able to affect appreciably even small plants until the air humidity rises enough to allow it to climb up the above-ground parts. That there is no inherent inability in the worm to attack rice during this period is evident from the fact that at any time between December and April it has been possible to secure infections in the laboratory by keeping the plants covered by a bell jar.

It is now easy to understand why it is that, though there is no month of the year during which paddy may not be found growing in some part or other of the infected districts, ufra is confined to the period from June to December. It is practically certain that the worms occur in the water of low-lying areas in the early months of the year, and probably a good many of them reach the growing boro paddy and get carried up or even, since the night dews are heavy

[1] "Diseases of Rice," p. 13.

in January-February, climb up above the water. That they can do so is evident from the attacks observed during this period on second growth aman paddy, though in Dacca, one of the chief boro areas, these have not been observed after January. There is even some evidence, as mentioned on p. 7, that January attacks have been seen on boro at Gobindapur. Those that do not leave the water are probably all dead a month or two after the fields are flooded. While in the water they do not multiply, and after they leave it multiplication can probably only proceed to a limited extent before the air becomes too dry to allow of copulation. They can feed for a time on the young inrolled leaves of the shoot bud, but when the leaf tissues mature feeding becomes impossible, as explained in the next section. The attack on the second growth from swamp aman paddy can be readily detected, as the shoots that spring from the old stubble very soon produce dwarf ears, and the worms congregate in and at the base of these and cause in them the same easily recognizable symptoms as in the main crop as it matures. But in the boro plants only the obscure symptoms of the early attack could be expected, and these are readily overlooked. From February or March on, no further migration would be possible, and the boro plants, though they may possibly bear desiccated worms in their lower parts, escape the injury to the ears and upper part of the stem that causes such losses in the later crops. They are harvested before the break of the rains would allow of further infection. In the same way, the aus paddy does not become severely attacked until June (the infection probably takes place in May), though worms must be present in the water of the lower-lying tracts from the first flooding of the fields. The aman is doubtless attacked at the same time but the attack escapes notice as the crop is still very immature. Worms have been found in the inrolled leaf buds of aman at the end of July, causing little external signs of disease as compared with what they cause in the ripe aus at the same period or in the aman later on ; and there can be no doubt that the invasion of both crops takes place at about the same time. That the damage to the aman is so much greater than to the aus is probably due to copulation only being possible after the rains break. Multiplication has not time to proceed far before the aus is harvested, but can continue for several months during the maturing of the aman.

Parasitic life of *Tylenchus angustus.*

The rice worm can only feed on certain parts of the plants. To those mentioned in the previous paper,[1] *viz.*, the young ear, the peduncle, the part

[1] "Diseases of Rice," p. 15.

of the stem just above the upper nodes, and the leaf sheath, must be added the young leaf blades inrolled towards the centre of the bud above the growing point. When seedling plants are inoculated, the latter is the point where the worms collect. They enter between the folds of the bud (never actually penetrating the tissues) and work their way round these towards the inner layers. Seedlings of about a fortnight from germination and six days after inoculation have been found to contain very many worms under the outer, still rolled, green leaf, and within the succeeding leaves and sheaths right in almost to the growing point. Naturally-infected aman plants have also been found in August, when about half grown, to contain pure cultures of enormous numbers of *Tylenchus angustus* in the white central part of the bud. In this case the plants were 2½ to 3 feet high, and all the leaves were removed until the central white bud, ½ to 2 inches long, was reached, when further dissection became difficult. The last few leaves around the growing point are so tightly rolled that they are not usually penetrated until loosened by the developing ear. Prior to this, the growing point is not reached and the worm feeds chiefly on the young leaves. Here it does not cause sufficient damage to kill the plant or even to cause any very marked symptoms except chlorosis and sometimes stunting. As the leaves mature, the outer cell walls thicken as described in the previous paper and feeding becomes impossible. Worms are scarcely ever found on any but the very young leaf blades, and when found they are probably only migrating, not feeding. It is not until the ear is forming and the worms collect at its base and above the top nodes of the stem that the strain becomes more than the plant can meet. It is quite possible to keep even severely infected young plants growing, but often impossible to get them to bear mature ears.

Feeding is exclusively by sucking out the juices from the epidermal cells of the infected parts. The spear which perforates the wall is only 9 or 10μ long, and is unable to penetrate any but unthickened or slightly thickened cell walls. Microtome sections of young infected leaf buds have not shown any very definite signs of injury to the cell-contents where the worms were feeding. There is no evidence of toxic action, so that the injury is presumably entirely due to continued removal of the cell sap. In other parts, as around the stem and base of the peduncle, the cells collapse and turn brown, but bacteria and fungi so rapidly follow the injuries caused by the worm that it is hard to separate their effects. The lower part of the last internode and the base of the peduncle may be shrunken to little more than the thickness of a thread.

Reproduction undoubtedly goes on vigorously on the plant during the period from June to November. Eggs and larvæ in all stages are found mingled

with adults within infected leaf buds and around the young ear. The length of the larval stages and the time that elapses from egg to adult has not yet been worked out either for the rice worm or for the allied *Tylenchus ribes*, so that there is no guide as to the rate of multiplication, but it is undoubtedly great.

Some of the inoculation experiments carried out at Pusa since the previous paper may now be described. Some of the earlier failures (I and III) are given as they led to the discovery of the close relation between atmospheric humidity and infection.

I. 28-3-'13, sowed paddy in 6 pots. 12-4-'13, seedlings numerous, about 6 inches high. Water was kept standing about an inch deep on the surface of the soil, which was puddled clay. Inoculated 2 pots by inserting pieces of infested peduncles and internodes bearing many worms under a leaf sheath. The material used had been desiccated for 5½ months in the laboratory. Inoculated 2 other pots by placing some of the same material in the water at the base of the plants. The remaining pots were kept as controls. During the following month dissected several of the plants in the inoculated pots and found in those inoculated through the water a few worms resembling *Tylenchus angustus*, some at the base and others within the shoot bud higher up. No ufra symptoms developed and the plants grew to maturity and headed out normally, giving 15 to 20 good ears in each pot in November. The plants were kept on a dry verandah, not covered, and the failure to develop an attack of ufra was doubtless due to this. The average of the 8 A.M. relative humidity recorded at Pusa during the two months after inoculation was 62·9 per cent.

II. 27-5-'15, sowed paddy in 24 pots. 28-7-'15, inoculated 12 of these with freshly collected (4 days old) aus paddy from Noakhali severely infested with *Tylenchus angustus* by placing pieces of diseased stems and ears in the water at the base of the plants. 10-8-'15, one of the inoculated pots showed definite symptoms of ufra. 14-9-'15, ufra distinct in 9 of the 12 pots and minor symptoms visible in the other 3. *Tylenchus angustus* present in quantity on the diseased plants. No symptoms and no worms in the 12 control pots. The plants were kept out of doors, and the success is to be attributed to the monsoon conditions to which they were exposed after inoculation. The average of the 8 A.M. relative humidity recorded at Pusa during the two months after inoculation was 86·1 per cent.

III. 30-12-'13, sowed paddy in 4 small pots (about 3×2 inches) and thinned to 1 plant each. Kept in incubator at 30°C., lighted through glass door. After about a week (when the seedlings were 2 inches high) inoculated 3 of the pots with motile worms, 2 being done with worms that had been swimming in water for a month, the third with worms freshly taken from a growing plant attacked by ufra. No infection resulted and not a single worm could be found to have ascended 2 of the plants which were dissected a week later. The third (one of those done with free-swimming worms) equally showed no signs of infection but was not dissected. The plants were kept in the incubator, the air inside which was dry except for the small amount of evaporation from the surface of the pots. Similar results were obtained when germinated seedlings were placed on 7-1-'14 in a glass capsule in the incubator with a few c.c. distilled water to which were added some 20 or 30 motile worms fresh from the diseased plant. Only 1 worm succeeded in climbing up a short distance up one of the shoots. Other experiments in which adults and eggs were used to inoculate seedlings in 6 of the small pots equally failed. They were kept uncovered, remaining indoors until the plants were too big for the pots

when they were transplanted with all the soil into larger pots on the verandah. So long as the humidity round the plants is not kept at a high level, infection cannot be secured. Occasionally, however, the natural monsoon humidity rises to a point, even within doors, when motion becomes possible and the plants can be climbed. Thus on 21-8-'17, two shoots were placed with their bases immersed in a few c.c. distilled water containing worms, the shoots projecting about 4 inches into the air. They were left on the bench, uncovered. By the 26th they were distinctly chlorotic, and on dissection were found to be full of worms in the bud folds right up to the apex. The 8 A.M. relative humidity recorded at the Pusa meteorological station averaged 87 per cent. for the five days the experiment lasted, while in the laboratory it exceeded 90 at 7 A.M. on most days, falling however to 80 or lower by noon. A similar experiment on 4-9-'17 only yielded a few worms in the basal half-inch, none having reached the upper part, when dissected 3 days later. This was a drier period than the last, the average 8 A.M. humidity having fallen to 83.

IV. 1-12-'15, sowed paddy in a glass basin in ½ inch distilled water, together with freshly collected actively motile worms, and kept covered so that the air remained saturated. 13-12-'15, found many living worms collected on a piece of young paddy leaf in the water and placed this in contact with one of the seedlings at water level. 19-12-'15, this seedling distinctly chlorosed. Examined and found heavily infected above the water level. 3-1-'16, many of the seedlings now well infected and the worms found in the shoot above water in all the inner layers of the leaf bud. 22-1-'16, repeated the experiment in two other basins, using seedlings 19 days from sowing. 27 to 30-1-'16, infection successful in seedlings of one basin, and 31-1-'16 in those of the other. Shoots chlorosed and worms found in the bud layers well above water.

V. 22-1-'16, transplanted 3 seedlings, 19 days from sowing in water, into each of 4 small pots. Kept standing in water covered by bell jars. 28-1-'16, inoculated a pot containing 2 seedlings (the 3rd had failed to survive transplantation) by inserting pieces of the inner white shoot bud of seedlings from the last experiment, containing worms, between a partly expanded leaf and the shoot. 23-2-'16, both the inoculated seedlings dying, having shown symptoms of attack about a week after inoculation. Only one *Tylenchus* could be found on dissecting the plants, the others having probably left the drying plants in search of fresh food. Of the 9 uninoculated seedlings, 1 was attacked by fungus (*Helminthosporium Oryzæ*) and the rest were perfectly healthy.

VI. 2-1-'17, sowed paddy in distilled water. 29-1-'17, transplanted 2 seedlings into each of 2 small pots, in one of which buried (about ½ inch below surface of soil) a few empty florets containing *Tylenchus angustus*, from plants from a plot that had ripened in late November and had been left in the field. Kept standing in water, covered by bell jars. 21-4-'17, examined the plants. One of the seedlings in the inoculated pot was apparently healthy and contained no worms; the other had brown stains on the sheaths as in ufra and there were a good many active *Tylenchus angustus* in the inner layers of the shoot. The 2 seedlings in the uninoculated pot were healthy and had no *Tylenchi* on them.

VII. The plot inoculated at Pusa in August-September, 1912, as described on p. 13 of the previous paper, ripened at the end of November and was a good deal damaged by ufra. It was left until March 28th, 1913, when the stubble both in it and in the uninoculated plot was cut and dug in to a depth not exceeding 3 inches. Local seed was sown the same day in both plots. Water was run on and kept standing as usual in paddy growing. By August there was a marked difference in the two plots, that previously inoculated being about 6 inches lower than in the other and

somewhat thinner. Numerous typical cases of ufra in the early stages were present in the former, and a few in the latter near the boundary (a 6-inch bund) between the two. In some plants it was estimated that between 500 and 750 worms and 200 eggs were present in the inner layers of the shoot bud, above the growing point, in greatest numbers about 3 or 4 inches above the latter. The photograph reproduced in Fig. 2 was taken on September 9th. Scarcely any crop was got

Fig. 2. Condition of the paddy plots in Experiment VII on Sept. 9th, 1913. The plot on the left is that originally inoculated.

from the inoculated plot, while about a quarter of the other was damaged. The stubble was left as before until the beginning of April, 1914, when it was all carefully hand-picked off and destroyed. On 7-4-'14 both plots were re-sown with local seed. No ufra appeared and a normal crop ripened in the last week of November.

VIII. The inoculated plots at Dacca, described on pp. 11-13 of the previous paper, were harvested in December, 1912, and the stubble destroyed, the plots being burnt over carefully. Paddy was grown on these plots without any trace of ufra, up to 1917, when they were sown with seed from an infected field as described under Experiment XI.

IX. Three small plots were transplanted with paddy seedlings early in the rains in 1913. 8-9-'13, 20 fresh infected central shoot buds from Experiment VII, with the outer leaves stripped off, were pinned down in the water channel near the inflow to the middle plot. The other plots received water from the same channel by inlets, one higher up and one lower down. 9-10-'13, the plant nearest the inlet in the central plot was removed. It had chlorosed shoots but no brown stains. It was found to be heavily infested in the inner layers of the shoots. 7-11-'13, the central plot now totally infected and signs of spread into the other two. 1-12-'13, the central plot almost all dried up and with little grain. In the other plots most of the plants were in ear, but there was a good deal of injury and some plants were barren. The photograph reproduced in Fig. 3 was taken

Fig. 3. Condition of the paddy plots of Experiment IX at the end of Nov., 1913.

at the end of November, 1913. 3-12-'13, the stubble was cut and the plot re-sown, some infected stubble being returned after sowing. Further details are given under Experiment III on p. 20 above. Ufra was well developed in July, 1914, and the photograph reproduced in Fig. 4 was taken on August 21st. On August

Fig. 4. Condition of the centre plot of Experiment IX on Aug. 21st, 1914.

26th the crop was burnt on the ground with kerosene oil and a fresh crop (both transplanted and broadcasted) put in on August 29th. This grew well and headed out normally in November with no trace of ufra.

X. Four plots were sown with paddy on May 24th and 25th, 1915. 28-7-'15, two of the plots were inoculated by placing fresh diseased shoots (4 days old) in the water. 15-8-'15, a few plants showed symptoms and were found infected with worms. 8-11-'15, the disease now well developed, almost all the plants being attacked in one plot, while the other contained numerous scattered cases. The soil of the latter was rather porous and the water-supply not well maintained on its surface. It ripened a moderate crop in December and was allowed to shed its grain, which germinated as mentioned above in Experiment II on p. 20. A permanent supply of water was arranged from July, 1916, previous to which it had been only watered intermittently. Ufra appeared in July, 1916, scattered plants showing chlorosed shoots without brown stains. One was examined and found infested with *Tylenchus angustus*. 22-11-'16, a good many plants had now well-marked ufra and were heavily infested. In the other plot the disease had been so severe the previous year that there was little grain produced and the self-sown plants were very few. 26-7-'16, transplanted a number of seedlings into this plot, but did not run in any water, so that the soil remained dry except when wetted by rain. There were some early signs of ufra in the self-sown plants in July, but the attack did not develop further and when harvested there was no evident disease and no trace of worms could be found in a large number of plants examined. The other two (uninoculated) plots remained healthy throughout. Here it would seem that standing water or at least a permanently wet soil is

necessary to allow an attack of ufra to develop. The stand of paddy in the "dry" plot was never strong and this may have helped to prevent an attack by keeping the air humidity in the plot at too low a level to allow of free migration. 3-2-'17, cut all the stubble in the "wet" plot and its control, discarding the "dry" plot and its control from further experiment. The stubble from the "wet" infected plot was stored in bags in the laboratory, while that from the control was burnt. The plots were then ploughed up. 2-4-'17, sowed local paddy seed in a seed bed. 5-7-'17, transplanted this into the "wet" plot and its control. 31-7-'17, returned the stubble that had been preserved in bags to the control plot, leaving the other untouched. No ufra developed in either plot, the plants heading out normally and giving a heavy yield in December. When the stubble was removed from the bags for use in inoculating, it was found to have rotted badly and to be powdery and damp. A number of the diseased ears were examined microscopically, and though they contained plenty of dead worms not a single living one could be found. The method of storage had obviously killed them, but the experiment at least confirmed the efficacy of removing the stubble and early ploughing in checking infection from the previous crop.

XI. The isolated plots at Dacca referred to as Experiment VIII were sown with seed taken from an infected field in 1917. Ufra developed towards the end of the rains and destroyed about a quarter of the crop.

The above experiments bring out certain points very clearly. No matter when the worms reach the field, ufra only develops in the monsoon unless the plants are kept covered so that they grow in a saturated atmosphere. When covered, an attack can be induced even in the cold, dry part of the year (Expts. IV and V), or later when it is still drier and very hot (Expt. VI). The attack is readily induced by leaving infected stubble from a previous crop on the field (Expts. VII and X), or by adding infected shoots to the water (Expts. II, IX and X). If the stubble be carefully hand-picked off or the infected crop burnt on the field, a perfectly healthy crop of paddy may be grown in soil that bore a severely diseased crop the previous year (Expts. VII to X). If the paddy is grown under "dry" conditions, an attack may be avoided even where there is infected stubble from a previous crop in the field (Expt. X), but the stand is poor and this may help to keep the air in the crop too dry to allow of migration even in the monsoon. In any case paddy cannot be successfully grown under such conditions. Infective matter does not remain in the soil if all the stubble be removed (Expts. VII and X), even though it can scarcely be doubtful that the worms have, to some extent, been set free in the soil by decomposition of fallen pieces of stubble. Infection may be carried by the seed under certain conditions, provided that (as must often happen) the seed is from a diseased crop and contains infected grains and empty florets (Expts. VI and XI).

As these last two points are of exceeding importance when considering methods of checking the disease, they may be further examined.

The soil in Experiment VII was allowed to dry out more or less completely (so far as the Bihar alluvium does so, which is only in the top few inches) between December, 1912, and March 28th, 1913. It was very much drier than some of the lower levels of the swamp paddy soils of Eastern Bengal at the same period. These may be still quite muddy at the end of February. So also in Experiment X the soil was kept dry from February until the rains in June.

The experiments detailed earlier are strongly against any infection from the soil being possible where standing water persists for several months after harvest; while those just described are applicable to the cases where the fields dry out, as the great bulk of them do, in the early months of the year; but they leave open the question whether the worms may not survive in muddy patches long enough to infect the succeeding crop. It has already been proved that they can live for at least 4 months if kept damp but not immersed in water, and this, combined with the fact that it is just in such muddy places that the second growth from the aman occurs on which ufra has been found as late as February, would be long enough for the purpose. But against this it may be argued that these low-lying places are amongst the first to be flooded by the rising water and such flooding would probably drown most of the worms, already weakened by their long fast, before the humidity rose enough to allow infection to take place. The problem presented by these muddy patches will be returned to below.

As regards seed infection, there is a good deal of evidence that it is not common. Seed from an infected crop has been sown several times at Pusa and at Dacca without causing an attack to develop. In Experiment VI the infected seed was buried in the soil at the same time as the seedlings were transplanted into the pots. The humidity conditions were such that the worms on resuming activity in the wet soil (there was no free water standing on the surface) could migrate to the seedlings. In another experiment the infected seed was buried on December 1st, 1913, and standing water was maintained for about 20 days, after which the soil was allowed to dry out for 18 days. On January 7th, 1914, 3 germinated paddy seedlings were sown in the pot and no infection was obtained though they were kept in a saturated atmosphere in standing water. In actual practice the conditions of Experiment VI are probably never realized. Broadcasted seed is never sown during the monsoon, but only in the earlier months when humidity is too low to allow of migration of the worm. In the monsoon months only transplanted paddy is put out and this could not carry contaminated seed. Again, in Experiment XI, deep-water paddy from an infected field was sown on January

1st, 1917. Owing to danger of infecting lower levels intended for paddy cultivation, the outlet to the water from the experimental area was kept closed. Sowing was done at an unusually early date. The young seedlings were doubtless readily climbed by the worms during the first month of their growth, since we know that the second growth shoots in infected fields that spring from the stubble after harvest are commonly infected in January. The water from the spring showers was held in the field, and though I am not in a position to judge of the effect of this on the humidity within the crop, it can hardly have been without some effect. I am, therefore, of opinion that there is still room to doubt, in spite of this apparently conclusive experiment, whether the use of seed from an infected crop is attended with much danger of conveying the disease under the normal conditions of cultivation. It is clear, however, that the disease can be conveyed by the seed and the exact conditions necessary to enable this to occur must be further inquired into.

The relative immunity of transplanted paddy.

As already stated transplanted paddy ordinarily escapes ufra. The explanation of this as regards the boro paddy has already been given; but this explanation does not apply to transplanted aus and aman.

Transplanted aus is chiefly found in high land in which the water is held by embankments. The fields are fed by rain water or by the surface flow from higher land. The general flood spill from the rivers does not reach these levels at all during the growth of the crop, and after harvest, when the bunds are not maintained, the transplanted aus fields are dry enough to walk through. Thus, unlike the great bulk of the rice lands, fields that bear this class of aus are dry for the greater part of the year. Furthermore, the stubble is very scanty as the plants are cut near ground level. Thus, even if the transplanted aus were to get infected, few worms would be left behind in the stubble after harvest, since they are very rarely found near the base of the plant, and these would have to survive a period of drying on the soil of some nine months before a new crop became available. This they might conceivably do if they remained in protected positions within the sheaths and glumes of the stubble, but such well-protected parts are mostly removed during harvest and any worms left behind would be likely to be set free into the soil by the heavy rainfall after harvest. Thus the conditions would ultimately be the same as have been proved by Experiments VII and X to free infected plots from the disease.

The same arguments apply to the bulk of the transplanted aman, except that the period between harvest and transplanting the new crop is less by

perhaps a couple of months. The fields intended for transplanting are very well prepared by ploughing in the spring as compared with those in which the broadcasted varieties are grown: being relatively high, they dry out early; and any stubble left is well ploughed in and soon decomposes. Where transplanted aman follows jute they are, in addition, usually flooded with at least a few inches of water for a couple of months before transplanting is done. This would be likely to finish off any worms that might have survived. But as stated on pp. 7 and 8, there are certain cases in which transplanted aman is reported to be attacked. The best authenticated are where the crop is transplanted in relatively low land, as in the areas in Feni where either transplanting or broadcasting is done according to the season, and in those in Noakhali where aman follows low-level aus. In the former case *roacha* is sometimes transplanted in land that is so low that transplanting has to be done into 18 inches or so of water, special varieties that will stand this depth being used. Where the former broadcasted crop was diseased, the transplanted is said also to get attacked. In such low land it is probable that conditions are more like those of the deep-water areas than the usual "sail" lands, and they probably do not dry out sufficiently for cultivation until relatively late in the year. They seem to differ but little from the conditions already known to lead to disease in the broadcasted crop. Where aman is transplanted after broadcasted early aus in Noakhali, the new crop is put in about a fortnight after the aus harvest, into water that must contain free-swimming worms if the aus has been diseased. The humidity conditions at the time are entirely suitable for migration on to the new seedlings, and the latter cannot be expected to escape. Except in such cases it is hard to see how ufra could be carried over from one transplanted crop to the next, unless conveyed in the seed, and this could only cause damage to the seed-bed, which is usually sown when the humidity is too low to permit migration.

The control of ufra.

There is as yet no indication that any variety of paddy is naturally resistant to the attacks of the rice worm. The number of distinct varieties grown is enormous and probably only a small proportion of them has as yet been exposed to infection, either natural or through artificial inoculation. Still there has been no report that any of the numerous kinds of deep-water aman grown within the limits of the infected tract can escape, the nearest approach being some of the "digha" or "Aswina" varieties, which mature early and so avoid attack to some extent. With these there is no question of natural immunity, but they merely do not give sufficient time between

infection and harvest to allow of much multiplication of the worms. The late *dighas* are liable to damage, as has been found in the case of the kind known as *aghani digha* in Backergunge. In the Feni Subdivision of Noakhali, an early maturing, long-stemmed variety called *haroli*, which ripens early in October, is grown in land where the water is liable to subside early. This kind suffers less from ufra than any of the other long-stemmed amans of the district, not because it is resistant but merely because the crop is well advanced when the disease usually begins. So also the boro paddies escape not because they are immune but because they grow at a season when the air is too dry to allow the worm to migrate; and the transplanted aus and aman varieties because they have little stubble after harvest and their fields are dry for much of the year. In every case that has been examined hitherto the reputed resistance of a particular variety or class has failed to stand closer test. Thus there is a variety of broadcasted aman called *khama*, much grown in Dacca District, which was said not to get the disease. Exposed to artificial inoculation it proved as susceptible as any other. It is usually grown on the sloping sides of the paddy *bils*, where early cultivation is possible after harvest, and it has been found that fields intended for *khama* paddy are usually already broken up and their stubble buried at the end of December or early in January. The straw is not very long, and the amount of stubble is decidedly less than in the kinds grown in the bottom of the *bils*. After ploughing, it decomposes quickly enough to expose the worms to a period of life in relatively dry soil which seems to be too long to enable them to survive until the following crop. Aus paddy is reputed to be immune in Dacca District, but the immunity is only apparent and is due to aus being grown on higher land in this area than in the more recent parts of the delta. Aus is often attacked in Noakhali and Backergunge. Even the transplanted amans, which escape in practically all parts of the infected area, have been reported, as mentioned in the last section, to take the disease sometimes when grown in relatively low land, and they are readily attacked if artificially inoculated.

Indeed it is scarcely reasonable to expect any such natural immunity to ufra, amongst varieties of paddy, as occurs so usefully amongst plants subject to fungal diseases. The rice worm is a coarse parasite as compared with most fungi. It never enters into intimate relations with the life of the host plant as so many fungi do, and instead of having to rely on enzymes to dissolve for itself a passage into the tissues (enzymes being bodies notoriously susceptible to alterations in the composition of the medium in which they work), the rice worm bores a hole in the cell wall mechanically with its spear. Unless there exist paddies with such thickened or hardened outer cell walls that the

spear cannot pierce them, it is little likely that immune varieties will be found.

In the earlier paper an extension of the growing of transplanted aman paddies was advocated. It was not then fully realized that the escape of the transplanted kinds in a sense accidental, being due to the relatively high levels at which they are grown, the early and good cultivation of the soil, and the late season at which they are put out. Now that it is known that there is nothing inherent in the transplanted varieties which makes them immune, and that transplanting does not cause the slightest difference to the course of an attack, other things being equal, this recommendation must be modified. The transplanted paddy is usually planted out several months later than the broadcasted is sown. This would no doubt give a long enough period, provided the soil was either cultivated or flooded, to kill out any worms left from the previous crop. But by that time the water would be too deep on the low-lying lands subject to ufra to allow of transplanting. Even if it were practicable, which it is not, it would be no use trying to avoid losses from ufra by transplanting paddy before the rains break into the fields which ordinarily get the disease. The worms liberated from the stubble at the first flooding would attack the transplanted crop as soon as the humidity rose sufficiently to allow of migration, just as readily as they attack broadcasted plants. Thus it is chiefly in the relatively small area in which the level can be altered so as to bring land that previously grew the broadcasted kinds to a height suitable for growing transplanted paddy that any benefit can be expected to result from transplanting.

Hence there seem to be only a few cases in which beneficial results may be expected through attempting to alter the varieties sown in ufra-infected land. One is the introduction of early maturing kinds, such as the *digha* paddies and *haroli*, and the other is re-arranging the levels of particular fields so that they may grow boro, *khama*, or transplanted aman, in place of long-stemmed aman. Mr. G. P. Hector, Economic Botanist to the Government of Bengal, to whom the first of these suggestions is due, is engaged in testing its practicability in certain areas ; while the second is of very limited application and is already well known to the ryots in many places. It will be referred to again below.

The growing of jute in some classes of infected land has been advocated with the idea that if the paddy crop could be replaced even for a year the worms would doubtless die out. In Noakhali a more profitable and, so far as can be ascertained, equally effective practice is to take first a crop of jute and follow it by a crop of transplanted aman put in in August. This cannot be done on the

lowest land, both because jute does not give good fibre if too early submerged and also because paddy cannot be transplanted if there is too much water. It is true that jute is often grown in land so low that there may be several feet of standing water at harvest time. In this case, however, no transplanted rice can be grown. Still, the moderately low land on which broadcasted aus can be grown is sometimes double-cropped with jute and paddy. The long period after the harvest of the previous crop, especially since the fields are flooded for probably a couple of months before the paddy is put in, is evidently enough to kill the worms. Wherever jute can be grown on land liable to ufra, its cultivation should be recommended once every few years.

Mr. Hector has found that it is more profitable, in some of the areas in Dacca District where broadcasted aus and aman are grown as a mixed crop, to replace the mixture with a pure crop of broadcasted aus followed by transplanted aman. In Noakhali and Backergunge, where both the constituents of the mixed crop get ufra, this practice would not be likely to reduce the disease: the transplanted aman would be infected from the aus. But in Dacca, where the aus escapes, the replacement of the broadcasted aman by a transplanted crop, put out several months later, should appreciably reduce the damage.

It has been amply demonstrated that the stubble from a diseased crop is exceedingly infective if allowed to lie on the soil until the sowing time approaches. In the greater part of the infected area little use is made of the stubble of deep-water paddy. The crop is harvested leaving all but the top foot or so behind, and what is left is not regarded as good fodder and is rarely gathered for the purpose. In the majority of the fields it is left to rot on the ground, and a thin crop of grass comes up through it and is grazed by the cattle. The result is that the stubble is trodden into a matted mass which keeps the surface of the soil moist in the early part of the year. In this condition it resists decay for a considerable time. Even when the fields are ploughed—often not till February—long wisps of half-buried stubble can be found in them. In some places the stubble is sold to the potters for fuel and ash, and the field may, in such cases, be fairly well cleared in December. In other parts a certain amount is removed and burnt in the fields or more usually as fuel in the villages. But in most of the really severely diseased areas little is done to clean up the lowest fields after harvest.

Experiment and observation alike show that if a field can be reasonably well cleared of stubble and then ploughed and kept dry for two or three months the worms can be killed out. Complete destruction of the stubble as in Experiments VII to IX is scarcely practicable under field conditions, but it is

quite possible to remove all but broken fragments and plough these in early so that they have time to decompose, as in Experiment X.

As the disease does not occur naturally in the neighbourhood of Pusa, only small plot experiments under very complete control have been practicable there and no field trials on a large scale could be made. Within the infected tract, field experiments and demonstrations have been hampered for want of trained staff; still something has been done to encourage clean cultivation amongst the ryots and, incidentally, certain difficulties in particular classes of land have been revealed.

The first field experiments * were started at Begumganj in Noakhali District in 1912. Three plots were selected, in one of which the stubble was burned on March 10th, 1912, in another it was burned on the same day and lime added at the rate of 30 maunds per acre a few days later, and in the third liming alone was tried, the stubble having been already ploughed in. The fields were then ploughed and the usual mixed crop of broadcast aus and aman (*bajal*) was sown in the limed plots while unmixed aman was broadcasted in the other. Early in August I visited the plots and found the aus ripe and perfectly healthy. Ufra first appeared in the unmixed aman in October, nearly a month after it was virulent in the surrounding fields. The latter were totally destroyed while the experimental plot gave a moderate yield. No attempt to check infection from the adjoining fields was practicable and the indications pointed to this as the source of the disease.

In 1913 a further experiment was made at Begumganj, the stubble being burned in two duplicate 1-acre plots of infected land after harvest in December, 1912, and then well ploughed and harrowed. Each plot was divided into 4 equal plots at sowing time (March 1st, 1913). One plot was sown with broadcasted aman, a second with the usual broadcasted aus and aman (*bajal*) mixture, a third with broadcasted aus which was followed by transplanted aman, and the fourth with jute similarly followed by transplanted aman. The three last plots escaped ufra, while there was some damage to the first. The yields were at the rate of 14 maunds per acre in the first plot (taking the mean of the two duplicates), 25 (13 aus + 12 aman) in the second, 34 (14 aus + 20 aman) in the third, and 12 maunds jute with 10 maunds rice in the fourth. Hence the damage cannot have been very great even in the attacked plot, of which only about one-tenth of the area was affected.

* All the field experiments in this section were arranged by the Bengal Department of Agriculture, to test the recommendations made by the writer in his previous paper and from time to time since. They were carried out under the supervision of Mr. G. P. Hector, Economic Botanist of that Department, in consultation with the writer.

In 1915 the experiment was continued in one of the two duplicate plots only. The treatment and cropping were the same as in 1913, except that the seed was not sown until April 10th and 11th. The crop on the first plot was destroyed by a flood. The second gave 16½ maunds aus but only a little over a maund aman, the latter having been almost destroyed by the flood. The third gave 22½ maunds aus and 12½ maunds aman. The jute in the fourth plot was much injured by flooding and only gave 3 maunds, while there was a yield of 17 maunds rice in this plot. All the figures are calculated to the acre. There was no ufra in any of the plots nor in any field immediately adjoining them, though there was some not far away.

In 1913 an experiment was made at Bikrampur in Dacca District. There had been total loss of the winter crop in 1912, and a somewhat similar state of affairs had prevailed, according to the local people, for several years previously. Seven acres of land in the middle of this infected area were marked off and the stubble burned in December, 1912. The area was then ploughed and harrowed five times between December 23rd, 1912, and February 12th, 1913. From March 12th to 20th the usual local mixture of broadcast aus and aman was sown after floating off the light grains in salt water. One acre in the middle received 20 maunds of lime also, a month before sowing. The crop was damaged by the rice Hispa, especially on the limed plot, but the yield was 44¾ maunds aus and 76¼ maunds aman, or a total of over 17 maunds per acre, which is quite a normal crop. No ufra appeared and the owners stated that it was the first normal crop they had harvested for some years. There was a lot of ufra in the surrounding fields, though it was said to be much less than in former years. Hence the experiment was not considered by Mr. Hector to be conclusive.

The Bikrampur experiment was continued in 1914, but no lime was added. Seven acres in a block were selected as before, the stubble burnt in mid-December and the land well ploughed between January and sowing time, which extended from March 13th to the first week in April. Five acres got the usual mixture of broadcasted aus and aman, while the other two were sown with jute and broadcasted aman mixed (a local practice). No ufra appeared and the yields averaged 11½ maunds each of aus and aman per acre, together with 17½ maunds per acre of jute.

In 1917 the experiment was repeated on a larger scale in over 50 acres in 5 separate blocks. Most of the area got deep-water paddy, but a little grew mixed aus and aman or jute and aman. The aus was free from disease, but about 12 acres of the aman, scattered through the 5 blocks, got attacked by ufra. The extent of the damage was not reported.

Around Nagori village, where the disease is extremely severe, 25 acres were brought under treatment in 1917. The treatment was simple stubble burning, with perhaps somewhat more thorough ploughing subsequently than is customary. Deep-water aman and *digha* paddy were sown. A good harvest was obtained, only 3 acres being attacked by ufra.

In 1916 field trials of the effect of burning the stubble in infected land were carried out under the orders of the Collectors of Tippera and Dacca.

In Tippera trials were made in the Chandpur and Sadar Subdivisions. In the former 64 plots of land were treated, comprising in all about 46½ acres. The stubble was burned after harvest and the land ploughed 10 times before sowing. There was no expert supervision of the operations, and no further details of the treatment were given. Nine of the plots were slightly affected by ufra, the rest escaped. In the Sadar Subdivision 12 plots, comprising nearly 11 acres, were treated. They included high, low, and intermediate levels. Some had been damaged by ufra for 5 or 6 years continuously, some for 2 or 3 years, some in alternate years. The stubble was burned after harvest and the land ploughed and harrowed 15 to 18 times before sowing. No ufra appeared in any of the plots, though one had an affected plot adjoining it. Still ufra was little prevalent in the district around in 1916, having only been reported to have damaged 30 acres in 12 square miles. There had been a flood of exceptional intensity in the monsoon of 1915, and a great deal of deep-water paddy was lost. This seems to have had a remarkable effect in reducing ufra the following year. It is probable that there was little contaminated stubble left to carry over the disease to the following crop.

In 1917, 14 acres near Laksam were treated as in the previous year. No ufra appeared; though in one case there was an attack close by. The disease remained relatively mild in the surrounding tracts.

In Dacca experiments were carried out in two widely separated areas in *bils* running into the high old-alluvium of the Madhupur Jungle. One of these, the crop in which had been severely attacked by ufra in 1915, was "bunded" across at the point where it debouched on the plain. The stubble was burned a considerable time after harvest, and as late as March 1st, 1916, the ploughing was still incomplete and the bund unfinished. As a result, the seed was broadcasted between six weeks and two months later than customary and the water rose before the plants were high enough to withstand injury. No ufra appeared, but the harvest was poor owing to the defective treatment the crop had received. Unfortunately here again there was little ufra in the immediate neighbourhood, the nearest diseased patch found being about ¼ mile away.

In the following year the bund was maintained and the experiment was supervised by the Agricultural Department. Sowing was done at the right time and a good crop, free from ufra, was obtained.

In the other area the *bils* selected were at a very low level and had suffered very severely from ufra for several years. The stubble was reported to have been burned in December, 1915, and the land ploughed early. The writer, however, examined the conditions in December, 1916, and concluded that it would be quite impossible to burn the stubble effectively in these particular *bils* so soon after harvest. In December most of the fields reported to have been burned were found to be still too swampy in the lower levels to enter, and even on February 28th, 1917, the central parts were still damp and soft. It would have been quite impossible with the means at the disposal of the workers to have gathered together and burned much of the stubble in the swampy parts before February, and even then a good deal would probably get pressed into the mud by the bullocks used for collecting it and for the subsequent ploughing. A very severe attack of ufra occurred in the treated fields, some of which gave practically no crop when harvested in November-December, 1916. In this case the treatment had not done the slightest good, but under the circumstances more could not have been expected. In 1917 the experiment was repeated under the supervision of the Agricultural Department, care being taken to postpone burning until the fields were dry enough to render it effective, which was not until February 21st. Two fields were treated and in both there were signs of ufra early in September. In one field about one-eighth of the crop was ultimately lost, in the other about one-fourth. For the first time for a number of years a paying harvest was obtained.

This last case introduces the main difficulty that is likely to be encountered in carrying out effective treatment of ufra. Throughout certain parts of the diseased tract low-lying patches of varying size are encountered in the middle of the paddy *bils*, which remain swampy well into January. In all of these which have had deep-water aman the stubble is left and usually gives a growth of small shoots and ears from December on until the ground dries, which may not be till late February. This only allows at most a month before the new crop is sown, as these low patches are always sown early, and not three months before the humidity rises enough to permit free infection. The second growth is liable to infection up to January in Dacca and into February in Noakhali. Before the ground is covered with water the worms have had only a short period in the dormant condition. They are then set free into the water in large numbers. Two months later the humidity is certainly high enough to permit migration and it is not unlikely that in these hollows, where the crop

becomes dense at an early period, the air within the crop approaches saturation sooner than elsewhere. It has been shown above that some worms can survive total immersion for at least 5 weeks even in the cold weather and for nearly 2 months if kept warm, so that by May we should expect a certain amount of active infection to be in progress in the crop. Probably the first infection is slight but all the conditions thenceforward are suitable for multiplication and migration. Thus we would expect to find the earlier attacks developing in these low-lying patches and spreading to the surrounding paddy, and this is exactly what the writer has been assured by cultivators in several places actually occurs. It is not suggested that all or the majority of the attacks originate from swampy patches. In the parts of Noakhali that the writer has visited, for instance, the attacks occur scattered through the paddy flats and often in different places in different years. But in the swampy, narrow, and deeply concave *bils* of the Madhupur Jungle the cultivators say that the infection often begins in the bottom patches year after year.

There seem to be only two ways in which these swampy patches can be dealt with, since there is little prospect of effectively burning the stubble in them. One is by drainage, and the other is by transforming them into boro paddy fields.

If they can be drained so as to dry out soon after harvest, no second growth is likely to come from the stubble and the latter can be removed and burned much earlier than is practicable at present. Thus they will be brought into conditions similar to those of fields where early burning and ploughing have proved effective in checking ufra.

The alternative is to deepen them so that they will hold standing water in which boro can be grown. This means abandoning the growth of deep-water aman in them, since aman cannot be grown after boro because the harvest of the latter is too late to permit of broadcasting aman. But this is no disadvantage, as boro is a more profitable crop than deep-water aman in most places. The difficulty is the water-supply. Standing water must be maintained in the boro fields until April, and this is only possible with irrigation, which is usually given about once a fortnight. Hence boro can only be grown, as already pointed out, along the banks of permanent channels, and if there is none near at hand where it is proposed to make swamp aman into boro land, one must be dug. The cost of this is considerable, but since these channels are the main means of communication (roads being useless where the country is submerged for half the year) the people are extraordinarily keen on getting new ones cut.

In certain parts of the Madhupur Jungle the people are already adopting the plan of cutting down and levelling the bottoms of the *bils* so as to transform them into boro fields, while the earth removed is used to raise the level of the margins high enough to grow *khama* paddy, which also escapes the disease. The extent to which this can be done by the unaided efforts of the cultivators is, however, limited, and the assistance of Government or of local authorities is required if it is to be carried out on a larger scale. It is probably one of the most useful ways in which local funds could be expended, as not only will communications be thereby improved but the produce of the land will be increased, apart altogether from ufra, because the varieties of paddy that can be grown on land thus treated are heavier yielders than the deep-water amans now found.

In the control of ufra it is evident that the methods must be largely directed to altering the conditions under which the rice crop is grown and so indirectly interfering with the activities of the parasite. The problem is more an agricultural than a pathological one. The pathologist can only aim at obtaining such a knowledge of the life-habits of the worm as to render it possible for the cultivator to arrange his practices so as to interfere as much as possible with its free development. There are not many places in India where the existing practices in rice-growing are so favourable to the peculiarly limited activities of *Tylenchus angustus* as those of the eastern districts of Bengal.

It is hoped that the results described above are sufficient to establish that much may be done to reduce the ravages of this pest. It has been conclusively proved that the destruction of the stubble of the winter rice will alone effect a great improvement. Where destruction is complete, or can be supplemented by a sufficient period of good cultivation of the soil before sowing the new crop, no worms will survive in those areas (and they are very large) in which the fields are dry enough to be taken in hand before the end of December. Where the fields remain moist into January and February it will still often be possible greatly to reduce the disease by burning at the right time and not attempting it before the stubble is dry enough to take fire. In the very muddy patches the growth of boro may be encouraged, and in many places a crop of transplanted aman taken after jute or (in some localities) after aus can with advantage replace the broadcasted aman. No one method will secure equally good results in all places, but each has its particular application and between them they cover a very high proportion of the fields subject to damage. But no one who has had any experience of the conditions of rice cultivation in Eastern Bengal, the enormous area concerned, the

lethargy of the cultivators, the difficulties of communications, and so on, can have any doubt but that progress will be slow and that it will be a labour of the greatest magnitude to effect a general improvement. The work all through has been hampered by the smallness of the trained staff available, and until this is remedied no adequate advance can be made.

Summary.

The work described above falls into three main divisions: A further study of the life-history and activities of the parasite, *Tylenchus angustus*, which causes the ufra disease of rice; an attempt to explain the anomalies in the behaviour of different classes of cultivated paddies to the disease, which were noticed in the earlier paper but which remained a complete puzzle until the close relation between atmospheric humidity and the movements of the worm on a dry surface was discovered; and finally the application of the facts ascertained to the control of the disease.

PUSA,

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